Status of Drainage Mapping from Airphotos in Indiana

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The construction of Indiana county drainage maps from airphotos has been in progress at Purdue University since the spring of 1946. It is believed that Indiana is the first to attempt a statewide program of drainage mapping from airphotos.

The airphotos used in this work were taken during 1937-1942 in connection with the United States Department of Agriculture map program. The prints were obtained from the Agriculture Adjustment Administration along with photographs of uncontrolled mosaics known as county index sheets. Approximately 25,000 prints were required for complete stereo-coverage of the state (1)*.

One type of airphoto interpretation is the conversion of the images on the airphotos into conventional signs (16, p. 32). Information required for the making of surface drainage maps can be obtained more completely from aerial photographs than by any other known means, especially in regions where the soils and relief of the land are complex and full of minor detail. When airphotos are examined stereoscopically, the terrain of an area stands out in relief (third dimension). The streams can be located more or less easily, depending upon the roughness of the countryside. It is a simple matter, then, to outline the stream systems on the airphotos with china-marking crayon. From these marked airphotos, surface drainage maps can be constructed.

A REVIEW OF THE MAPPING PROCESS

The first step in preparing a detailed drainage map from airphotos is the procurement of a base map on which to transfer the airphoto

* Figures in parentheses refer to entries in the Bibliography, page 189.

drainage information. It was found that available county maps could be used with certain modifications. A county-drainage base map is made by tracing the land-section grid of one of the General Highway and Transportation Maps which were prepared in 1937 by the State Highway Commission of Indiana in cooperation with the U. S. Department of Agriculture and the Bureau of Public Roads. This base map (scale: one inch equals one mile) is made on tracing paper so that it can be used as a working drawing. Variations in the distances between section lines, as recorded on the original county maps, have necessitated minor base-map corrections. By using the congressional township lines as control lines, the base map is checked with the airphotos and made to agree with the airphoto grid.

The airphotos of Indiana are standard 7″ x 9″ and 9″ x 9″ contact prints obtained from the Agriculture Adjustment Administration. They have an approximate scale of 1:20,000, or three inches per mile. With the aid of pocket stereoscopes all discernible drainage ways are marked on the airphotos of a county with dark-blue china-marking crayons. (See Figure 1.)

After the drainage ways have been marked, the section corners are indicated on the airphotos by small crosses. (See Figure 1.) The positions of the section corners are located by comparison of the landmarks and physical features recorded on the airphotos with those symbolized on the General Highway and Transportation Maps. The exact location of the section corners on the airphotos is necessary because the construction of drainage maps involves the transfer of the airphoto drainage information in units of one square mile in order to minimize accumulative error.

The drainage information is transferred from the marked airphotos to the paper base map by means of a transferring device built around a classroom delineascope. The transferring device has a focusing adjustment so that the images of the airphoto section-line grid can be made to fit the paper base-map grid. It was found that this adjustment is required because of slight differences in the scale of the airphotos.

Upon the completion of the penciled paper drainage maps, inked cloth maps are made from them. Established symbols are used in presenting the drainage information—major streams are shown by double lines, perennial creeks by heavy single lines, and intermittent drainage ways by light single lines. Cities and highways are about the only culture shown on these county maps, for it is desirable to eliminate as many confusing items as possible.

FIGURE 1. Stereogram of a sandstone-shale area in Lawrence County, Indiana. This section of the state is very rough topographically. The left airphoto print has been marked for drainage.

FIGURE 2. Status of drainage mapping in Indiana. Cross-hatched counties are those for which drainage maps have been completed.

COMPLETED COUNTY DRAINAGE MAPS

Surface-drainage maps for 37 counties in Indiana have been completed as of March 24, 1949. (See Figure 2 and Table 1.)

TABLE 1

LIST OF COMPLETED DRAINAGE MAPS OF INDIANA COUNTIES
(Prepared from Airphotos)

	County	*Date Completed*	*Director*
1.	Parke	June, 1946	M. Parvis
2.	Fountain	July, 1946	S. T. Yang
3.	Montgomery	July, 1946	J. D. Mollard
4.	Putnam	September, 1946	M. Parvis
5.	Vermillion	October, 1946	M. Parvis
6.	Vigo	November, 1946	M. Parvis
7.	Brown	November, 1946	M. Parvis
8.	Union	January, 1947	M. Parvis
9.	Ohio	January, 1947	M. Parvis
10.	Fayette	January, 1947	M. Parvis
11.	Switzerland	January, 1947	M. Parvis
12.	Franklin	February, 1947	M. Parvis
13.	Floyd	March, 1947	M. Parvis
14.	Clay	April, 1947	M. Parvis
15.	Henry	May, 1947	W. S. Pollard, Jr.
16.	Rush	May, 1947	C. R. McCullough
17.	St. Joseph	June, 1947	M. Parvis
18.	Marion	August, 1947	M. Parvis
19.	Monroe	October, 1947	C. J. VanTil
20.	Dearborn	October, 1947	M. Parvis
21.	Bartholomew	October, 1947	M. Parvis
22.	Jackson	November, 1947	F. K. Dawson
23.	Clark	November, 1947	J. C. Stevens
24.	Starke	January, 1948	M. Parvis
25.	Shelby	February, 1948	M. Parvis
26.	Cass	February, 1948	M. Parvis
27.	Ripley	April, 1948	M. Parvis
28.	Grant	April, 1948	M. Parvis
29.	Blackford	April, 1948	M. Parvis
30.	Jefferson	May, 1948	M. Parvis
31.	Hancock	May, 1948	C. R. McCullough
32.	Martin	July, 1948	M. Parvis
33.	Porter	October, 1948	M. M. Davis
34.	Decatur	November, 1948	M. Parvis
35.	Tippecanoe	January, 1949	M. Parvis
36.	Scott	February, 1949	M. Parvis
37.	Hendricks	March, 1949	C. R. McCullough

Mapping Schedule

A schedule has been established and is being followed whereby counties in various parts of the state are being mapped for drainage.

Special studies by graduate students have resulted in the preparation of drainage maps for Porter, Jackson, Rush, Montgomery, Parke, Henry, Clarke, Monroe, and Fountain counties (2, 3, 7, 8, 10, 13, 14, 17, and 18). (Also see Table 1.)

At present, drainage maps are partially constructed for Wayne, Laporte, Morgan, and Owen counties; and airphotos of widely scattered counties are in the process of being marked for drainage.

County Maps Show Drainage Patterns

Drainage maps exhibit drainage patterns which can be used by the highway engineer to help him identify soil types of an area. Knowledge of soil types present enables him to locate suitable highway materials and to design the highway surface to give maximum performance.

Three county drainage maps are herein presented to show drainage patterns characteristic of different geologic materials found in various physiographic regions of the state. Jefferson County has an area of approximately 362 square miles and is partly in the Ordovician limestone and shale area and partly in the Illinoian glacial drift area of southeastern Indiana. Martin County, with an area of approximately 340 square miles, is mostly in the residual soils area of southwestern Indiana; Mississippian limestone outcrops in the eastern part of the county, and Pennsylvanian sandstones outcrop in the remainder of the county. Tippecanoe County, having an area of approximately 488 square miles, is mantled with Wisconsin glacial drift; it lies in the central part of the state.

Figure 3 is the drainage map of Jefferson County. The eastern third of Jefferson County lies in the Dearborn Upland. It is a hilly area with subdendritic drainage patterns characteristic of those occurring throughout the Ordovician limestone and shale area of the region (12). Most of the remainder of the county lies within the Muscatatuck Regional Slope; however, the extreme western part is within the limits of the Scottsburg Lowland (6, p. 66). This central and western portion of the county ranges from a nearly level tableland in the east to a gently rolling slope in the west (5, p. 136); drainage patterns in this section are the subdendritic ones typical of the Illinoian glacial drift region of the state (12).

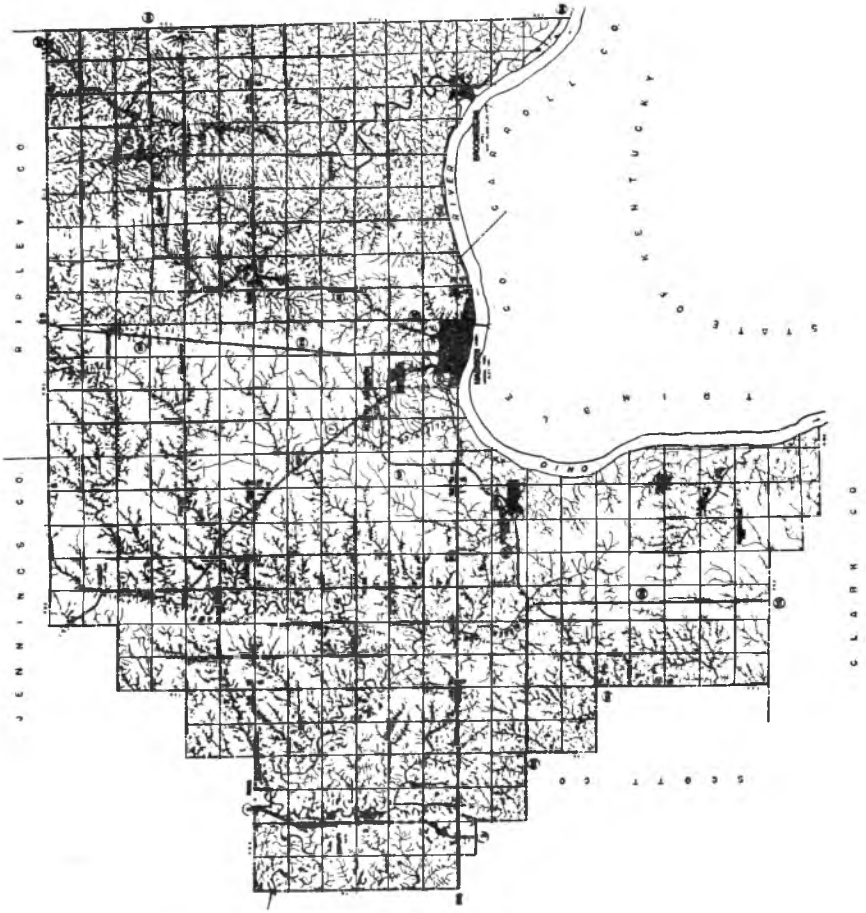

FIGURE 3. Drainage map of Jefferson County, Indiana.

Figure 4 is the drainage map of Martin County. Most of Martin County lies within the Crawford Upland; however, a small area in the central-western part of the county is in the Wabash Lowland (6, p. 66). The surface of the county is quite rough, for the greater part of it is in the driftless area of the state. Its predominant drainage patterns are the typical subdendritic ones found throughout the sandstone areas of southwestern Indiana.

Figure 5 is the drainage map of Tippecanoe County. Tippecanoe County lies within the Tipton Till Plain (6, p. 66). The surface of the county is a rolling plain. Drainage patterns are the typical dendritic types found in Wisconsin glacial drift areas (12). These dendritic pat-

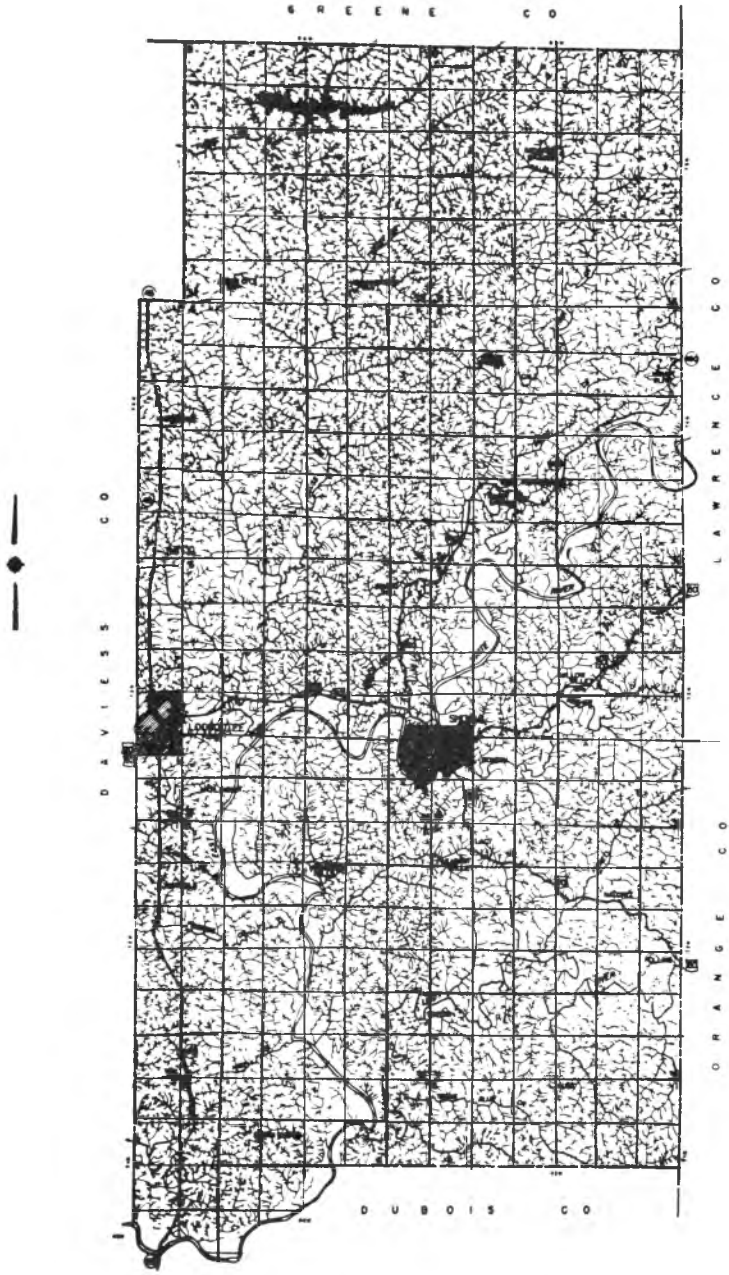

FIGURE 4. Drainage map of Martin County, Indiana.

terns are coarse-textured in the till plain areas. They become medium-to-fine-textured on the morainic ridges. There are no developed drainage patterns on the granular terraces since drainage is internal.

Costs

Cost records have proved that accurate drainage maps can be constructed from airphotos in a reasonably short period of time (9). Drainage maps for Dearborn and Tippecanoe counties have been selected to show the relationship of costs for counties of different terrains, and correspondingly different geologic materials, as well as to show the effect of base-map "correction" on the cost data. The total number of hours and the time distribution required in the construction of these two maps is presented in Table 2.

TABLE 2

Time-Distribution Data Required for Drainage Mapping

County / *Area*	*Dearborn* 315 sq. mi.		*Tippecanoe* 488 sq. mi.	
	Man Hrs.	mh./sq. mi.	Man Hrs.	mh./sq. mi.
Preparing Base Maps[1]	16	.051	98	.201
Marking Airphotos[2]	77½	.246	205	.420
Transferring Drainage Data[3]	67	.213	82	.168
Tracing Final Map[4]	60	.190	90	.184
	220½	.700	475	.973
Supervision[5]	150	.476	150	.308
Total	370½	1.176	625	1.281
Date Report Completed	October, 1947		January, 1949	

1 Includes one paper and one linen map.

2 Includes marking section corners, physical features, and checking drainage marking.

3 Includes visual checking of working map with marked airphotos.

4 Includes physical features (highways, etc.) and checking.

5 Pro rata; includes spot checking of marked airphotos and preparation of report.

Analysis of the data in Table 2 reveals pertinent cost factors in the mapping program. Each map required about 1¼ man hours per square mile of area to complete it. Of this time about ¾ to 1.0 man hour per square mile was required for the mechanics of construction of the maps;

this included preparing the base maps, marking drainage ways on the airphotos, marking section corners and physical features on the airphotos, transferring drainage data from the airphotos to the base maps, checking, and drafting the final map. The ¼ to ½ man-hour-per-square-mile supervision time included spot checking of the marked airphotos and the preparation of the written report which accompanies every map when it is presented to the Highway Commission.

It required four times as many man hours per square mile to prepare the base map for Tippecanoe County as for Dearborn County. Very little "correcting" was done on the base map for Dearborn County, while the base map for Tippecanoe County was completely "adjusted" to agree with the land-section grid as recorded on the airphotos. This "correction" is partially reflected in the transfer of drainage information from the airphotos to the paper base maps in that the time of transfer for the Tippecanoe County drainage map was reduced .05 man hours per square mile from the time required for the Dearborn County drainage map.

The unit time required for marking drainage ways on the airphotos of Tippecanoe County was nearly double that for Dearborn County. Though the drainage ways in Dearborn County are multitudinous and spaced at close intervals, the terrain of the county is rough and good stereo-vision is obtained when viewing it on the airphotos. The marking of these drainage ways on the airphotos, though tedious at times, was a direct and deliberate process. On the other hand, the marking of the drainage ways on the Tippecanoe County airphotos was a slow and laborious process because many of the airphotos of Tippecanoe County, having been taken immediately after a rain, are of poor quality photographically. Many localized mosaics had to be assembled to determine the continuity of the stream systems; and morainic areas, with their haphazard drainage systems, required considerable and careful attention.

The decrease in the unit time for inking the final map of Tippecanoe County can be accounted for by the fact that the drainage pattern of the county is of coarser texture than that of Dearborn County.

The supervision time for each county has remained constant since the start of the mapping program.

THE STATE DRAINAGE MAP

Even before the mechanics of the method of constructing drainage maps from airphotos of Indiana counties had been worked out, the concept of a state drainage map had formed in the minds of Joint Highway Research Project engineers.

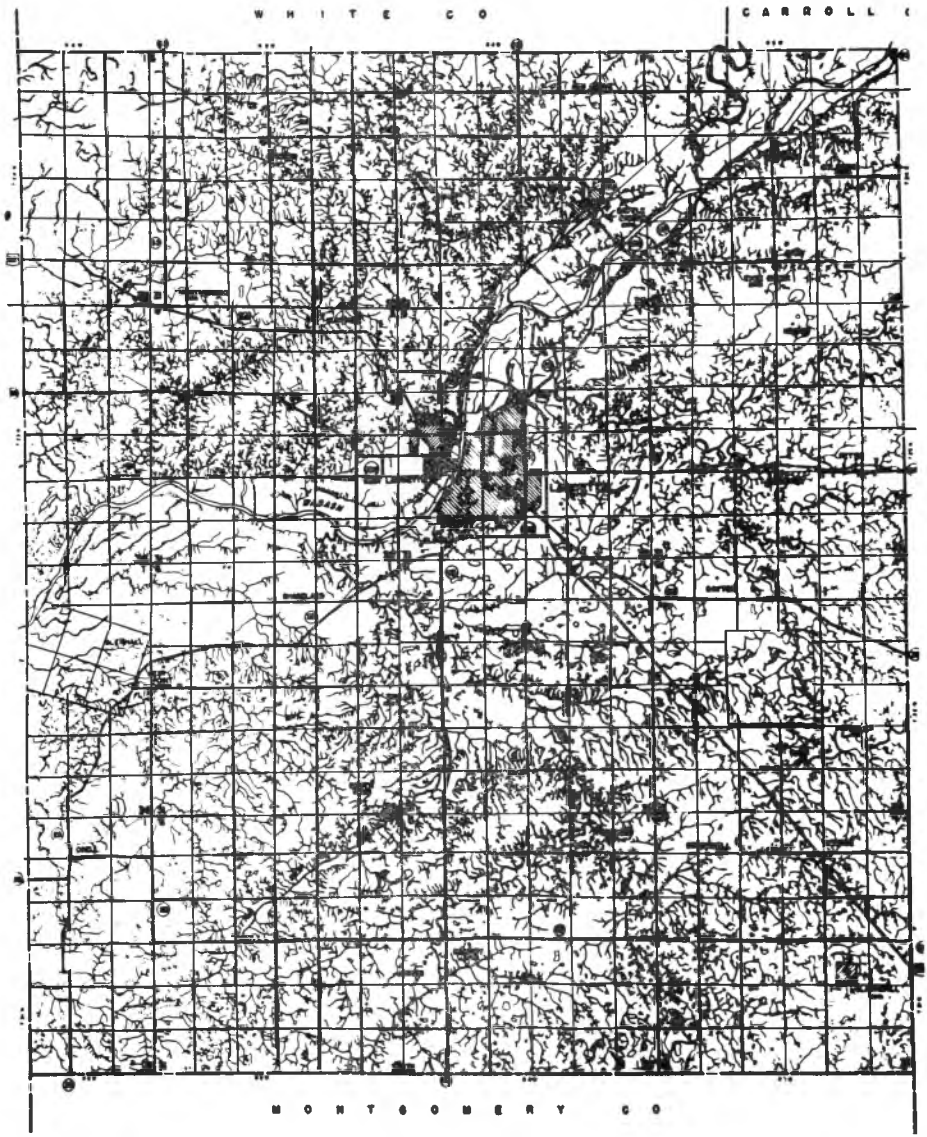

FIGURE 5. Drainage map of Tippecanoe County, Indiana.

Since 1933 highway engineers and surveyors have made use of the Conservation Department's "Streams and Lakes" map for information concerning drainage systems in Indiana (15). In the past in determining the area of a drainage basin, if it were less than 25 square miles in extent, the practice of "driving around" it was followed. If the drainage basin area was larger than 25 square miles, its area was heretofore "estimated" from the "Streams and Lakes" map. This map is quite general, probably because of the purpose for which it was intended. Because of the demand for greater accuracy in the determination of large drainage areas, a detailed drainage map of the state is being prepared.

Base Map

The first step in preparing the state drainage map (as in the county mapping) was the procurement of a base map on which to transfer the county drainage information. The state drainage base map was made by tracing the county boundaries and land-section grid of the Geology Map of Indiana which was prepared in 1932 (4). This base map (scale one-fourth inch equals one mile) was made on cloth. Only the county boundaries were inked at the time it was traced.

Method of Construction

Photographic reproductions of the completed county drainage maps are made to the scale of one-fourth inch equals one mile. The separate county grid systems on the state drainage base map are checked with those on the small-scale photographic drainage map prints. Wherever necessary, adjustments are made in the county grid systems of the state base map.

The county grid systems are then inked on the state base map, and the map is ready for the transfer of the drainage information. The base map is placed on a light table over the ratio prints of the county drainage maps, and the drainage systems of successive counties are inked onto the state base map in square-mile units. As was pointed out in the construction of county drainage maps, this minimizes accumulative error.

State and U. S. highways, along with cities and incorporated towns, are the only physical features transferred to the state base map; it is desired not to "clutter" the state drainage map with excessive culture. (See Figure 6.)

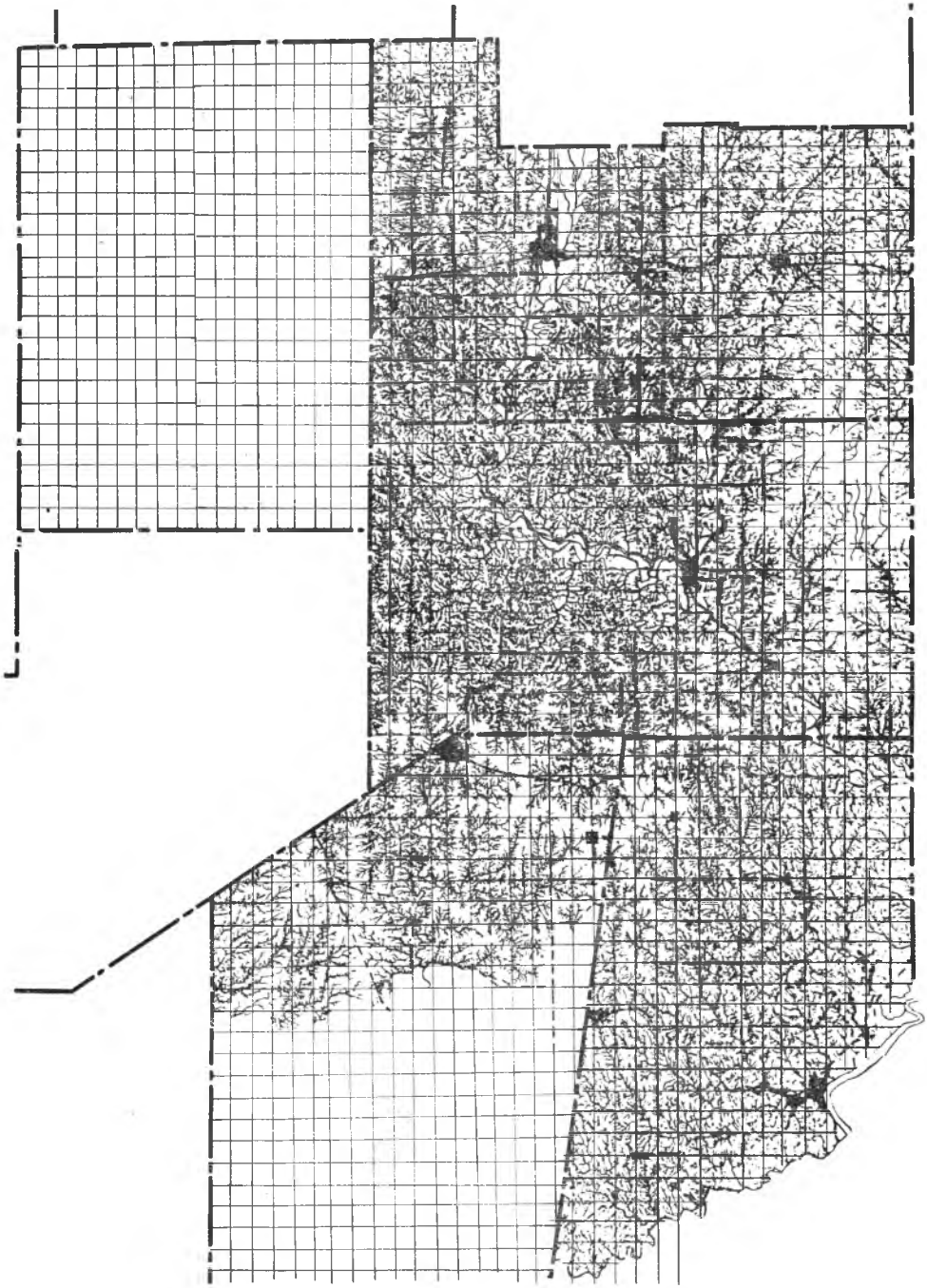

FIGURE 6. State Drainage Map. Completed portion includes Fayette, Union, Franklin, Dearborn, and part of Ripley counties (as of March 15, 1949).

Amount of Detail Transferred

All the fine detail of the reduced county drainage maps is being transferred to the state base map. This maintains the pattern of the drainage systems which is one of the vital elements in the identification of regional soils and underlying rocks.

Costs

Accurate records have been kept of the time required for the inking of the drainage systems onto the ¼-inch-scale state base map. These costs are recorded in Table 3.

TABLE 3

Time Distribution for Transfer of Drainage Data to State Map

County	*Area*	*Man Hours*	*Mh./sq. mi.*
Franklin	394 sq. mi.	62	0.158
Dearborn	315 sq. mi.	46½	0.148

In other words, it is taking a draftsman less than 10 minutes per square mile to produce the state drainage map after the base map has been prepared.

HOW INDIANA'S STATE HIGHWAY ENGINEERS USE THEIR DRAINAGE MAPS

Indiana's state highway engineers are making use of completed county drainage maps in estimating drainage-basin acreages used in the design of new and replacement highway structures. State highway design engineers, especially, have found that acreages of drainage basins can be measured accurately on the county drainage maps.

One of the duties of the surveyor in making a location survey of a bridge or road is to obtain the areas of the drainage basins of the stream or streams crossing the proposed highway. When his field notes reach the Central Office, these drainage areas are carefully checked with areas planimetered on the county drainage maps. If the two quantities do not check (within a reasonable amount), rechecks of areas in question are made in the field. This precaution is taken because of possible channel changes or other stream diversions since the date of the airphoto coverage.

The State Highway Commission has frequently complied with the requests of county officials for areas of certain drainage basins by measuring the areas on the drainage maps.

Some work is also being done in determining runoff factor constants by studying drainage patterns found on the drainage maps. If the texture of the pattern is coarse, a low constant would normally be required. Runoff factor constants are used in standard runoff formulas along with drainage-basin acreage estimates for the calculation of the size of waterway openings of proposed highway structures.

INDIANA DRAINAGE MAPS AID OTHER ENGINEERS

Agencies other than the State Highway Commission of Indiana have found use for Indiana's county drainage maps. The maps are being used for special projects such as studies of water supply, drainage and water problems, and possible artificial lake sites.

Departmental heads in various universities are learning of the existence of these maps. Departments which have requested and received copies of designated maps or information concerning their development are: (1) Soil Conservation Service, Agricultural Experiment Station, Purdue University, (2) College of Engineering, Cornell University, (3) Department of Geology, Notre Dame University, (4) Mississippi Geological Survey, University of Mississippi.

Highway departments of three states have been furnished information concerning the development of drainage maps from airphotos. They are the Ohio Department of Highways, the Planning Survey of the Mississippi Highway Department, the State Highway Commission of Maine.

Some of the governmental agencies in Indiana which have shown interest in the mapping program and/or which have been furnished copies of maps are: (1) the Bureau of Government Research, Indiana University, Bloomington, Indiana, (2) the Indiana Conservation Department, (3) the Flood Control and Water Resources Commission of Indiana, (4) the Indiana State Board of Health, (5) the Soil Conservation Service, U. S. Department of Agriculture, Fowler, Indiana, (6) the District Geologist, Geological Survey, Department of the Interior, Indianapolis, Indiana.

On February 25, 1949, a list of the 36 drainage maps, completed to that date, was furnished to the Purdue University Library for forwarding to the Army Map Service.

Consulting engineers and water supply contractors are discovering the value of the maps. Information concerning their development has

been translated into Spanish and printed in the *Journal of the Cuban Society of Engineers.* Photographs of the transfer table have been furnished the Prairie Farm Rehabilitation Office, Regina, Saskatchewan, Canada. Three magazine articles pertaining to the drainage mapping have been published—one in the May 25, 1947, *Indianapolis Star Magazine;* one in the June, 1948, issue of *Better Roads;* and one in the October, 1948, issue of the *Highway Magazine.*

From various parts of Indiana have come requests from seven county surveyors, a state highway bridge project engineer, and an agricultural agent for information on the procedure for obtaining copies of completed maps. In many instances it has been possible to furnish the maps.

SUMMARY

The status of drainage mapping from airphotos in Indiana may be summarized as follows:

1. 37 county drainage maps have been completed as of April 1, 1949.
2. A state drainage map is being prepared. Drainage information from seven county maps has been transferred to the state base map as of April 1, 1949.

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All airphotos used in connection with the preparation of this report automatically carry the following credit line: "Photographed for Field Service Branch—PMA—U.S.D.A."